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ANALYSIS OF REPLACEMENT CRITERIA FOR NAVAL CONSTRUCTION FORCE EQUIPMENT

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THESIS

ANALYSIS OF REPLACEMENT CRITERIA FOR
NAVAL CONSTRUCTION FORCE EQUIPMENT

by

James Reginald Stark

March 1975

Thesis Advisor: F. Russell Richards

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The replacement of capital assets in the construction field is a very complex matter involving factors both internal and external to the equipment itself. This, coupled with the magnitude of capital invested, requires a comprehensive approach to replacement decisions if the equipment inventory is to be managed effectively. This thesis explores the criteria upon which the construction equipment replacement decision is based in two arenas: commercial construction and the U. S. Naval Construction Force (NCF). The

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Analysis of Replacement Criteria for
Naval Construction Force Equipment

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All have made writing a thesis a little less painful to the author.

J. R. S.

I. INTRODUCTION TO THE PROBLEM

A. UNIVERSAL PROBLEM

Modern civilization has become, gradually through some phases and at an accelerated rate in others, vastly dependent upon what is known as capital equipment. Capital equipment is a term which encompasses all types of durable machinery. Whether a modern state's economic base is principally industry, maritime or agriculture, the capital equipment employed is a primary component. The ongoing need and availability of this equipment, then, is a basic tenet to the future of that country and, in a more microeconomic sense, of its component industries and firms making up those industries. Herein lies the concern for effective replacement.

Replacement of machinery is a matter involving a myriad of factors, some external and some internal to the equipment itself. Replacement is not, in most instances, a result of a singular dramatic incident; rather it is a function of a gradual succession of events which lead up to such a decision. Terborgh noted:

> Capital goods live out their mortal span in an atmosphere of combat, a struggle for life as bitter, as intolerant of weakness, as the tooth and claw of biological competition . . . The denizens of the jungle enjoy a limited security by reason of the continuity and stability that prey upon them. Machines, on the contrary, must defend themselves in a world where new species spring up overnight, where the landscape is never twice the same, where the fitful winds of change are never stilled.
>
> There is another contrast between biological and mechanical competition. In the former, death strikes suddenly, by violence; in the latter it comes usually

by degrees, through a process that may be defined as functional degradation. It is a kind of progressive larceny, by which the everchanging but ever-present competitors of an existing machine rob it of its function, forcing it bit by bit into lower grade and less valuable types of service until there remains at last nothing it can do to justify further existence. A capital good that can no longer hold some useful function against competition is a mechanical cadaver, whether buried or not . . . In the bloodless warfare of machines, life is taken, as a rule, by stages. [Ref. 31]

That this process is incremental, involving both objective and subjective factors, adds to the difficulty of its solution. And because of the number and magnitude of variables impacting, the replacement decision process must be finely tuned. Watson noted in Ref. 34, " . . . even the most brilliant intuition and longest experience are insufficient to handle all the factors in their proper perspective. This in no way minimizes the use and value of astute judgment."

The industry with which this thesis is concerned is construction. The foregoing discussion was not specifically aimed at this industry but it certainly pertains. If there is one particular contrast of construction to the general concept of industry, it is the uniqueness of every project. Whereas most industrial processes are primarily repetitive in production, construction is an aggregation of iterative subfunctions (perhaps) to produce something one-of-a-kind. This makes construction equipment management even more complex.

There is a one particular phenomenon operating on the current economy which adds importance to the analysis of every investment decision studied which warrants mention here. It is the rate of

price inflation. For construction equipment, its projected rate between prices of September 1974 and December 1975 ranges between 18% and 30%, depending on the type of equipment [Ref. 18].

The capital equipment replacement problem, then, is a universal one. The importance of how successfully it is accomplished is part of the very lifeblood of an industry. Construction is no exception.

B. A U. S. NAVY PROBLEM

Construction is, of course, accomplished by many organizations and firms. There is within the United States Navy a force whose mission is military construction primarily in support of U. S. Marine Corps and naval shore operations. Called the Naval Construction Force (NCF) and composed primarily of Mobile Construction Battalions known commonly as Seabees, accomplishment of their mission requires an equipment inventory currently valued at $132 million. Management of this construction equipment entails great complexity.

For the several years prior to 1974, NCF equipment procurements averaged approximately $14 million annually. A given figure such as this will of course buy less and less equipment as soaring inflation cuts into the quantity received. Coupled with this, the Congress appears further apt to decrease defense spending. In addition, a commensurate decrease in the NCF mission has not been perceived. A net result of all this is a stepped up requirement to continually pursue more effective methods to manage the Navy construction equipment inventory.

C. STATEMENT OF THE PROBLEM

As in all industries there are many options involving the question of capital equipment displacement. It can be done by overhaul, equipment transfer (from other sites), subcontract, lease/rent or replacement.

This thesis seeks to address the replacement option as approached by the Navy Construction Force equipment managers. More specifically it takes issue with the concept that replacement of Navy construction equipment is almost solely based on one criterion: age of the equipment. It is considered that the predominance of the age factor is an oversimplification of the solution to a complex matter. The question studied: what are the criteria and other factors, in addition to age, inherent in the NCF equipment replacement decision?

II. SCOPE AND APPROACH

A. SCOPE

The subject of capital equipment replacement is both a complicated and extensive one. Conceptually it is as long as it is wide and its implications are far-reaching. Depending on the equipment intensity of a particular organization or industry, the replacement problem may be the driving factor in even the most basic decisions its management makes. In others, equipment replacement may be a secondary or tertiary decision tenet of that organization. Regardless, if conducted conscientiously, the process of implementing an effective equipment replacement

program is not a simple one--it covers, rather, a spectrum from being mildly complicated to very complicated.

This study does not pretend to analyze all aspects of every capital asset replacement problem. To do so, obviously, would inundate the reader with works on the magnitude of a fair-sized library. This work is, however, a conceptual look at the decision factors pertinent to replacement of one type of physical asset, namely, construction equipment. Unlike some general classes of equipment (e.g., automotive), the use of construction equipment is limited to a particular industry. The industry itself is a multi-faceted one. However, upon investigation one finds that, varied as the industry is, there are certain matters regarding equipment replacement which are common throughout. As mentioned below there are both theoretical and practical approaches which have been studied in order to develop a profile or benchmark by which to compare an even more specific area of asset replacement. That subject area is the approach utilized by the U. S. Navy in the ongoing inventory management of the Naval Construction Force's (NCF) construction equipment.

There are several assumptions at the base of the study which should be noted at the outset. First, the need for the equipment is assumed to be one of an ongoing nature. It does not attempt to validate the equipment requirement. This implies that the NCF mission is long-term and parallels the concept in the commercial world of a "going concern." To the knowledge of the author, this assumption is unquestionably valid.

Secondly, the primary area considered deals with acquisition of capital equipment which will serve to replace assets previously held in the inventory. In a sense this is related to the premise above in that it is downstream from initial acquisition or initial need development. It is the process which Terborgh terms "primary replacement" which cites new acquisition vis-a-vis replacement by equipment under the same ownership, say, from another jobsite [Ref.32]. In the NCF equipment management environment, it was found that this "primary replacement" was the principal area of emphasis. Accordingly, this premise is considered supportable.

The third assumption is that the equipment inventory for a given equipment code (ECC) or family or class has a relatively even-age distribution. This, in effect, minimizes the effect an "age hump" has on management of certain ECC. Due to the Naval Construction Force build-up for Vietnam, Seabee equipment unfortunately does not currently fit this profile in many equipment codes; some are "humped" with old equipment. Accordingly, this assumption is not as incontrovertible as the aforementioned. It is admittedly self-serving in that it serves to dampen the predominant impact of the age factor on the replacement decision.

The Civil Engineer Support Office (CESO) of the Naval Facilities Engineering Command (NAVFAC) manages the entire fleet of civil engineer support equipment for the Navy. This equipment inventory includes both automotive and construction codes. The subject of equipment replacement criteria is equally applicable

to both of these types of equipment. There have been numerous studies conducted and reams of reports written concerning automotive assets and their replacement both by commercial and government groups. The sheer numbers of automotive units, their highly visible service, general type of use and cyclicality are reasons for the intense study received. In contrast, construction equipment studies were not found to be that common. Certainly the capital invested would point to a need for comprehensive study.

There are many types of construction equipment for the myriad of specialized tasks of building. The field is further complicated by the many variables encountered in the type of use to which an equipment unit may be subjected (soil conditions, maintenance support, operator quirks, remote location, etc.). These all preclude development of replacement theory which would espouse general applicability. Even a study of the small segment the NCF performs in the overall construction industry spectrum encompasses nearly all variables. Such is the nature of the industry. Hence, the tenor of this thesis is the discussion of factors which affect replacement and how they are considered conceptually in equipment replacement deliberations.

B. RESEARCH APPROACH

There were three basic areas from which information was sought: theoretical, industry and the Navy. They were not mutually exclusive by any means. Theory was extracted from the written word of library and technical publications. As one

might expect there was considerable writing on the general subject of capital assets which dealt mostly with industrial plant equipage. Material specific to replacement acquisition of equipment used in construction was relatively scarce.

The next area researched was the criteria used by industry and was composed of two sub-areas: equipment manufacturing concerns and construction companies. Equipment companies were interviewed in order to include both the seller and marketer views on replacement. The contacted manufacturers built weight-handling, paving and the top-of-the-line earth-moving equipment. Information was further developed from construction companies operating on an international basis through interviews with managers and assistant managers of the equipment and tool procurement. In respect for privacy and in accordance with explicit requests, the companies will not be further identified. These theoretical and industry concepts are discussed in Chapter III. As will be developed in Chapter IV, there are numerous and extensive managing and operating differences between industry and the Navy. The basic problem of equipment replacement is, however, mutual. The information from theory and industry coupled with these differences provide a means of comparison from which to analyze the criteria utilized in managing NCF equipment.

The management organization of the NCF construction equipment was the third and principal area of research. Such robust organizations as Congress and the President's Office of Management and Budget which are so far-flung from the actual replacement

decision, yet which impact so heavily on such matters, stack the management system with many vertical layers. This study concerned itself primarily, however, with the actual decision-making agency (CESO) and its handling of the parameters laid on it from above. Information was obtained through discussions with Naval officers and civilians tasked with the decision to replace. They are listed in Appendix A. Criteria and factors upon which Navy construction equipment replacement decisions are based are discussed in Chapter V.

The task remaining to be accomplished is a comparison and evaluation of those replacement criteria cited and used in theory and industry and in the Navy. Based on that analysis, recommendations are made regarding which criteria are pertinent to NCF equipment replacement decisions.

III. THEORETICAL/COMMERCIAL APPROACH

As noted in preceding chapters, the main thrust of this treatise is to analyze the particular criteria used by the U. S. Navy in supplying replacements for the construction equipment in the Naval Construction Force inventory. In order to provide a base line for such a discussion, concepts extrapolated from references listed in the Bibliography and from the aforementioned industry interviews are cited herein.

A. THE CONCEPT OF "ECONOMIC LIFE"

1. Definition

Within management, "economic life" is a common consideration which dwells right at the center of many far-reaching decisions. For a given physical asset under deliberation, its economic life could encompass many different factors depending on the area of responsibility of the one studying it. Consider the simplistic example of a bulldozer which is owned by A and rented to B for a certain project. To A, the prime economic life consideration regarding the equipment is the entire cost and revenue profile of that dozer over an extended period of time. This must include not only the costs and income derived from B's use of the tractor and those of other users but also the ongoing costs which must be paid irrespective of whether the bulldozer is being rented. Thus, the economic life factors of the owner's equipment decision are more comprehensive and longer range than those of the temporary user. In contrast, B must be concerned with the economics of using a bulldozer over the short haul, figuratively speaking. Assuming the tractor is the one best-suited to accomplish the task, the machine-hours estimate becomes the basis of the "life" of the dozer by B's definition. The economic factors he must weigh are concerned with whether or not he should rent from A (or from some other lessor) or buy the bulldozer himself. The point is, the subject of economic life can wear a coat of many colors. To submit definitions without full description of the decision environment is, admittedly, over-simplification. This

notwithstanding, as further preface to the matter of the equipment replacement subject, several definitions follow.

In his study, Douglas [Ref. 30] defined economic life as ". . . the age at replacement, in years, that maximizes the profits returned to the owner. Since a chain of replacements is involved (normally), the economic life pertains to a <u>class</u> of equipment rather than to a specific <u>piece</u> of equipment." This is shown graphically in Figure 1.

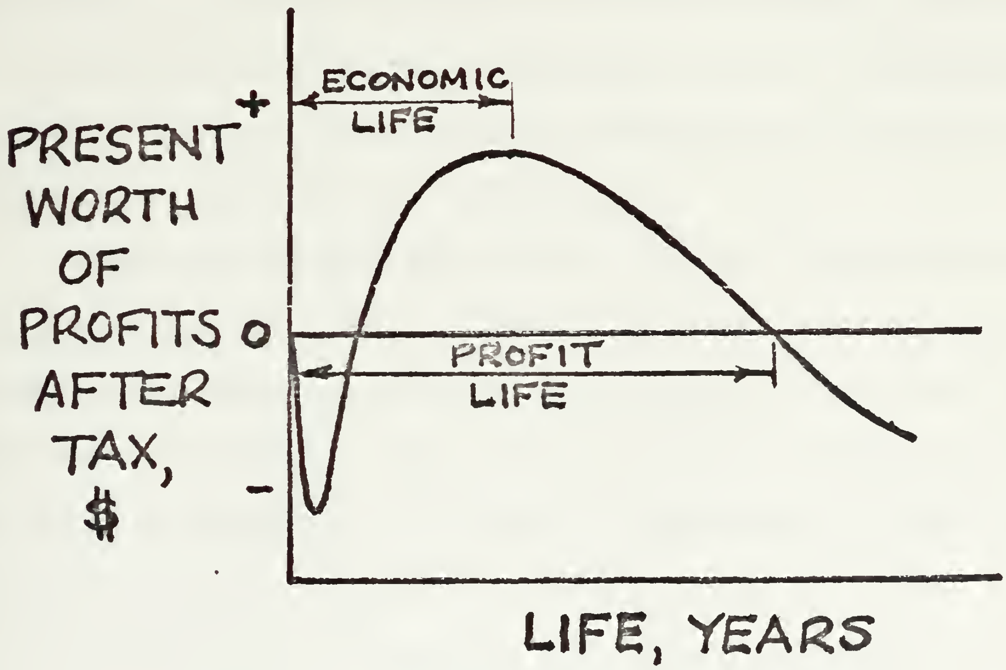

FIGURE 1. ECONOMIC LIFE OF EQUIPMENT

He went on to observe that ". . . the life that maximizes profits is considerably less than the maximum that will still earn a profit for the owner." Watson cited the period which results in a "total capital recovery cost (primarily depreciation and equipment acquisition interest expense) and operating cost for a range of service lives . . . that will yield minimum annual cost." [Ref. 34] This is shown by the graph of Figure 2.

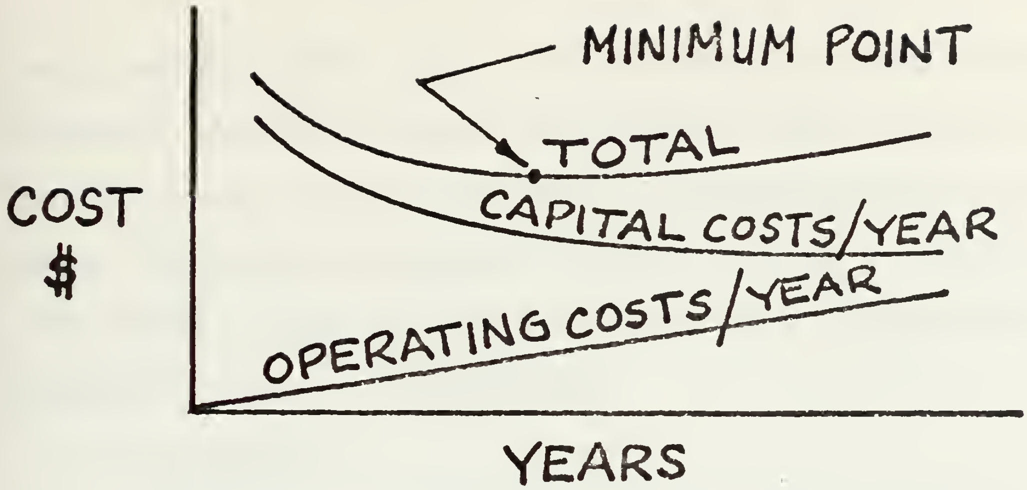

FIGURE 2. DETERMINATION OF ECONOMIC LIFE

Caterpillar, in their Equipment Economics study, described the key to the most economical replacement time as "whether the cumulative cost per hour becomes progressively higher or lower with added machine hours." [Ref. 7]

Thuesen described economic life as "the time interval that minimizes the asset's total equivalent annual costs or maximizes its annual revenues" and equated this to the "optimum replacement interval." He went on to warn, however, "(that) rarely is the economic life used to determine how frequently an asset should be replaced. Several reasons. First the economic life is valid as a replacement only under the restrictive assumption that all future replacements are the same as the replacement under consideration with regard to first cost, salvage value, operating expenses and net income produced. Second, reasonably good data describing the costs of an asset are rarely available at the time of its purchase. A third reason is that the decision to retire an asset is not usually made at the time of purchase . . . due to factors in existence shortly before the time of

replacement." [Ref. 33] It is noted, then, that deriving the economic life of an asset does not in itself solve the replacement question. There are factors which impinge upon the matter which disallow the decision being made "in a vacuum." How effectively these factors are considered is dependent on the approach applied by management.

2. Approach

Due to the magnitude of the capital investment involved, equipment replacement decisions must be conducted in a managed arena. As Hackamack observed in Ref. 11, ". . . the first crucial step toward the efficient handling of replacement programs is obtaining recognition of top management that replacement problems do exist and that they should be handled on a systematic basis." He is convinced that an effective modernization program should accomplish the following:

a. Alert management to profitable replacement opportunities.
b. Collect data that are pertinent to the decision.
c. Estimate the profitability of the proposal.
d. Determine the need for funds and the funds available.
e. Select the best investment opportunities for the available funds.

There are, of course, numerous factors to discuss with which management must deal in approaching the matter of equipment replacement. At the leading edge is one which was discussed earlier as a basic assumption to this thesis but nonetheless bears reiteration--the question of the need. Information must be developed which describes in finite terms the need or requirement for which the equipment is proposed. Without a firm grasp of this matter the resultant decision will be a futile exercise.

Related to this is the fact that every requirement study regarding construction equipment will be a unique one. The same analysis should not be used for every prospective equipment decision but rather should be tailored to meet the demands of the particular situation [Ref. 11]. In developing a format for a general approach, it certainly should be designed to satisfy the conditions unique to the company's operations [Ref. 13]. Likewise, Watson cited requirements which he believed each equipment analyst must accomplish:

a. Choose an evaluation method which best suits his needs.
b. Choose the cost components that are applicable to the particular replacement problem.
c. Determine the availability and accuracy of the components.
d. Determine the future value of the components.
e. Combine the necessary components into a series of costs that reflects future increases in operating costs as equipment grows older.
f. Combine future operating costs with capital recovery costs to determine the economic life of the project.
g. Select an acceptable rate of return to calculate the project payoff. [Ref. 34]

Knowledge of the equipment is an obvious necessity. It must be recognized also that, as Watson notes, " . . . there is a distinction between deteriorating or 'diminishing efficiency' equipment and sudden failure of 'constant efficiency' equipment . . . The lifetimes of the former can be extended indefinitely if their parts are repaired or replaced as necessary." [Ref. 34] Construction equipment is of the "diminishing efficiency" type and deliberations regarding its management must reflect this aspect. The repair versus replace question is discussed in later sections.

Management is in a position to consider the reason for a given equipment replacement and should do so explicitly. In Ref. 11, Hackamack cited eight economic reasons:

a. Produce better products.
b. To remain in competitive position.
c. To increase output.
d. To provide stockholders with a greater return on investment.
e. To cut maintenance costs.
f. To reduce waste and the scrap factor.
g. To lower direct labor costs.
h. To reduce work-in-process inventories.

He further noted four non-economic reasons which are not necessarily mutually exclusive of the foregoing:

a. Improving the safety of an operation.
b. Reducing the human-error factor.
c. Increasing the efficiency of operations.
d. Increasing the adaptability of equipment.

This list is not all-inclusive. Depending on an organization's goals or mission, the decision basis could be one or a combination of factors. Whatever the case, it should be known at the outset and explicitly handled.

It is noted in summary there are no rigid formulae, no cookbook instructions which guarantees to management that their selected approach will even be effective, let alone the optimal. The judgment they exercise is indeed paramount.

B. REPLACEMENT ALTERNATIVES

One facet of the construction equipment replacement problem warrants discussion at this point. The tenor of this thesis presupposes that replacement equipment will be acquired to meet a future construction need and endeavors to cite criteria which

deal with particulars of the question. There are, however, several basic alternatives to procuring new equipment which justify mention.

One obvious alternative to buying is renting or leasing equipment. Commonly, a company will opt for this solution when faced with a limited use requirement for a particularly high cost unit. Without doubt, the major factors involved here are the period of required use and availability of capital. Another option akin to the lease/rent one is to subcontract the task.

Sound, realistic management of equipment resources is a necessity and effective construction scheduling can preclude the requirement to acquire new equipment. This can apply on both an inter- and intra-project basis. This includes shuttling equipment from jobsite to jobsite; it also encompasses the concept of determining what other types of equipment in the existing inventory can be used for the given task.

Another alternative solution is to repair or overhaul the existing asset. The typical design of today's construction equipment encompasses a myriad of subassemblies. Upgrading of the basic unit through repair and/or replacement of these components produces a viable option indeed. Undoubtedly, there are thousands of construction units in operation currently where the only evidence of its real age is the old chassis. In light of the current accelerating inflation rate, the attractiveness of this alternative continues to grow.

Considerations of this type must be weighed as part of the replacement decision process.

C. CRITERIA AND OTHER CONSIDERATIONS

There are many factors of varying complexity and impact which must be dealt with in making sound construction equipment replacement decisions. As a result of researching theoretical works and commercial practice, eight factors are considered particularly relevant to the type of decision in question. These factors, which are listed and discussed under "Criteria" below, are not meant to represent an all-inclusive list for every replacement decision for development of such a list is considered by this writer an impossible task due to the wide spectrum of use of construction equipment. This notwithstanding, sound management requires development of a systematic listing of all factors relevant to a given decision. There are other matters which are also important to these replacement decisions which are discussed in the subsequent section. Admittedly, there is a fine line between criteria and "other factors" and the distinction is not considered an important one.

1. Criteria

a. Age

On the surface, age is a seemingly uncomplicated matter to consider. Each specific unit of equipment has an age which should be readily extractable from even the simplest record system. In many organizations age may be the key, perhaps even the sole, factor in a given equipment replacement decision. The equipment inventory manager must be aware of the implications of the age listed for equipment under deliberation.

Age is normally based on the manufacturer's date of issue, i.e., the model year. Assuming it was acquired for a specific immediate need and was received directly from the factory (as in the case of many equipment orders placed by large construction companies) for continuing use, age is indeed simple. There are, however, cases where the purchase was via a dealer's showroom where it may have been for, say, a year. In essence then the books may show a one-year-old machine which was, practically speaking, brand-new. As will be discussed in Chapter V, the Navy has a similar consideration because some of its new equipment goes directly into a mobilization inventory to be held in readiness for several years prior to being rotated for use. It is seen, then, that non-use or delayed use of new equipment can distort its age.

Another way in which age is measured is the number of hours or miles logged on its meter. This is a more valid yardstick to the equipment manager in that it supplies him more meaningful data regarding that equipment's particular history. Commonly, age records show both chronological age in years and use-age in hours or miles.

Related to this is the age either in years and/or in hours or miles allowed by the Internal Revenue Service for depreciation write-off. Understandably, this factor is always a prime consideration in commercial construction. Close comparison of the actual usage versus the corresponding depreciation allowed is a key to effectively managing the equipment on hand.

Good analysis of that data is an essential input to the decision of when to replace these existing assets.

Due, at least in part, to its ease in identification and derivation, age is ofttimes the single criteria used to "flag" equipment for study in a given replacement cycle. If such a criteria is necessary to a management approach, it is as valid as any. It should, however, be tempered for as Terborgh notes in his initial MAPI book, " . . . no productive facility should be exempt from challenge (replacement consideration) merely because of its youth." [Ref. 32]

Age is an essential criteria in equipment replacement. The components which are inherent in its definition must be recognized by the equipment manager and weighed in light of his decision environment.

b. Obsolescence

Thuesen stated in Ref. 33 that there are two basic reasons for considering replacement of a physical asset: physical impairment (which will be discussed in the next section) and obsolescence. He said obsolescence " . . . occurs as a result of the continuous improvement of equipment. Often the rate of improvement is so great that it is an economy to replace a physical asset in good operating condition with an improved unit." Caterpillar defined obsolescence as "the result of inefficiencies of a presently owned machine relative to a replacement machine with technical improvement." [Ref. 7]. Terborgh noted that it must be defined not in terms of age or decrepitude,

but rather as a "matter of relativity, not an attribute of the asset itself." [Ref. 32]

The weight of obsolescence in the replacement decision process is a function of competition as perceived by the commercial construction executive. Hackamack described a primary " . . . problem concerning equipment replacement is that an old machine will probably still function as effectively as it did when it was new but the fact remains that technological advances in productivity may have outmoded it. The cost of production on old machines increases or remains the same; however, competitors may have incorporated the benefits of lower production costs through utilization of new equipment with the latest technology." [Ref. 11]

Obsolescence is a concept which is relatively easy to understand but difficult to quantify. The writer encountered only one observed estimate of an obsolescence cycle for any type of construction equipment. During an interview with an equipment company representative, he noted that new breakthroughs on bulldozer design occurred approximately every five to six years.

Obsolescence is a measure of factors external to the equipment. It is subjective in nature. Not unlike other criteria and factors discussed herein, this element serves to highlight the requirement for a firm grasp of the entire replacement decision environment to manage construction equipment effectively.

c. Physical Impairment

The term physical impairment is considered self-descriptive. Depending on the type of construction equipment in question, measurement of physical impairment can be a simple or not-so-simple task. In contrast to the aforementioned obsolescence, this trait is internal to the machine. It can deal a machine a single swift, traumatic blow or it can, as Terborgh said, "take its life by stages by a kind of progressive larceny." [Ref. 32]

A major equipment accident at a construction site is a common example of instantaneous physical impairment. The magnitude of cost to repair these machines relative to initial cost often makes the decision to replace (vis-a-vis repair) a simple one. Indeed, some organizations have percentage cost to repair and age relationships set as a matter of policy guidance to the equipment manager. A corollary to this is that one construction company interviewed carries "total damage insurance" and through its claims liquidation repairs the damaged equipment. The decision it is then faced with is whether to retain or sell subsequent to the insurance-paid repair. A quirk of this criteria is that it often answers the question <u>when</u> to replace but leaves unanswered the question of <u>whether</u> to replace.

The other aspect of physical impairment is much more subtle. It is the "progressive larceny" to which Terborgh referred. It is a gradual happening which "may lead to a decline in value of service rendered, increased operating costs, increased

maintenance costs or a combination" according to Thuesen [Ref. 33]. Because of its subtlety the costs associated with this physical impairment must be monitored continuously to be managed effectively. Normally the maintenance costs will plot as a continuous curve for an equipment group. As such the curve must be inspected for trends as it is plotted separately and in combination with other costs (e.g., owning and operating costs). Analysis of such trends is essential to the replacement question. Indeed, in its treatise on equipment economics, Caterpillar cites the cost of maintenance and repair as "the largest single operating expense for earthmoving equipment." [Ref. 7]

There is a case which falls between the two previously mentioned. There are times when an extensive repair or overhaul is contemplated which is a result of prolonged use. It is, as was noted earlier in this chapter, an alternative to replacement.

d. Performance

The concept of performance or productivity is another factor which is necessarily at the heart of replacement deliberations. It is a function of factors both internal and external to the machine, a fact which adds somewhat to the complexity of its analysis.

The internal factors relate to the built-in capacities of the machine and how well engineered the component parts are married to the overall designed output. It deals also with the quality of workmanship with which it is built.

There is a factor which is both internal and external. It is the effectiveness of the man-machine interface considerations designed into the unit which abet its operation toward the designed maximum. It is of no use to have the highest capacity machine on site without an operator with corresponding ability or experience. This operator training, which is only indirectly related to the machine, can affect its productivity significantly. This is stating the obvious, but nevertheless operator training must be considered. One construction company interviewed indicated that in their equipment acquisition deliberations they explicitly sought the "top-of-the-line" equipment due to the physhological aspects of obtaining maximum output from both man and machine.

Another machine-external facet which requires consideration is how well suited the selected equipment is for the job. This, too, has significant effect on a unit's productivity. Judgment of this type is possible only with knowing equipment lives and project requirements and conditions in detail. The manager of a central equipment inventory is unfortunately not always able to accomplish such a detailed approach. There is assistance available, however, from either his field staff or from equipment company representatives who will study job requirements and recommend equipment accordingly.

One final point on productivity relates to the terms of study: both long-run and short-run data should be analyzed. Of particular importance in both the long and short is the ton per hour or cubic yard per hour moved and the attendant costs.

In addition, the amount of down-time logged over the long-run bears constant monitoring. Taking into account the site and working conditions, any downturn in the former or upturn in the latter would be significant in any replacement deliberation.

e. Resale

It was noted in research that one particular criteria was emphasized tepidly in the theoretical texts but very obviously considered a dominant factor in industry practice when both the construction companies and equipment manufacturers discuss replacement. It is the equipment's resale value. It should be a consideration in equipment selection as well as in the decision of when to replace.

As noted in one equipment management handbook, for many owners " . . . potential resale or trade-in value is a key factor in their purchasing decisions, since this is a means of reducing the investment they must recover through depreciation charges. High resale value . . . can reduce hourly depreciation charges, lower total hourly owning costs and improve the owner's competitive position." [Ref. 5]

The equipment resale subject can best be summarized in Figure 3 on the next page. It plots used bulldozer auction prices as a percentage of their original list price based on sales at 43 Forke Brothers auctions in 26 states in 1973. The bulldozer class shown covers such models as International Harvester TD-25, Allis-Chalmers HD-21 and Caterpillar D8.

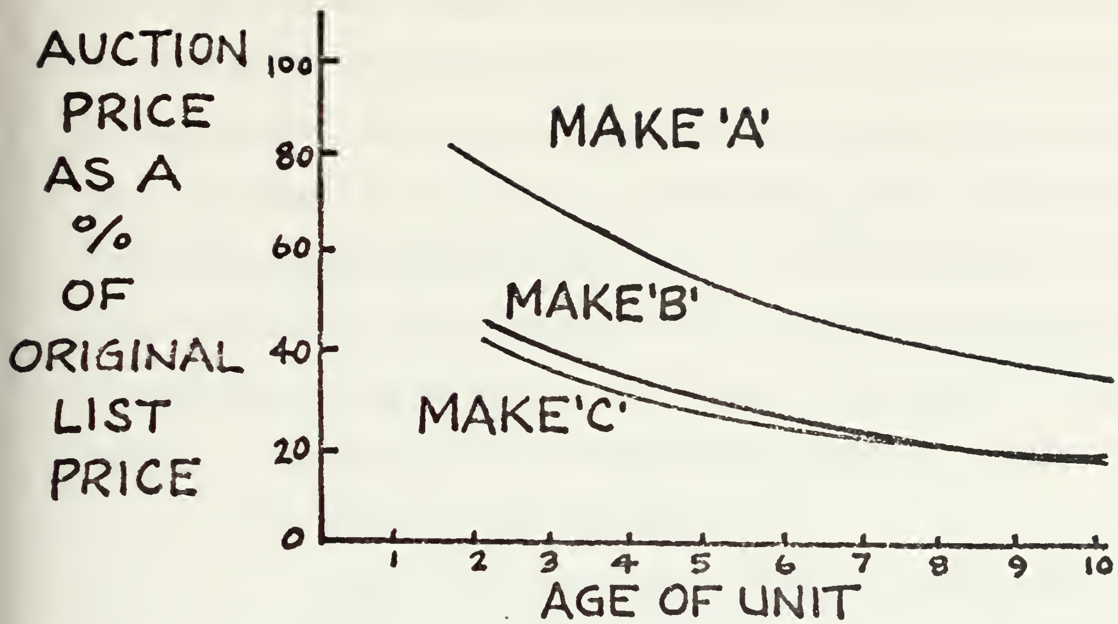

FIGURE 3. USED EQUIPMENT AUCTION PRICES

As can be seen, price differences and therefore cost recoupments can be significant when comparing equipment makes particularly in the early years.

f. Need

This criteria has been discussed previously. At the risk of redundancy, it is noted here for emphasis. Suffice it to say that no sound equipment replacement decision can be reached without comprehensive study of the need for which the equipment is proposed.

g. Availability of Money

Perhaps because it is a very general factor which is external in nature to the equipment itself, the availability of procurement funds is not treated comprehensively at all in any of the references. For similar reasons, its treatment here

will be likewise. This approach, however, should not subordinate its importance. There are numerous factors which affect the availability of funds which can be attributable to either the organization or economic climate. They will not be discussed here. It should be noted, nonetheless, that there are questions regarding procurement funds such as how obtained, in what amount, when available and at what cost that must be answered in the replacement deliberations early on. The import of such matters cannot be overstated when replacing capital assets.

h. Cost of the Equipment

There are two basic categories of costs relating to physical assets; ownership and operating/maintenance. As noted previously when discussing economic life, minimizing the combined total of these costs is a prime tenet of effective equipment management. To achieve this the equipment manager must be fully knowledgeable of cost make-up.

Ownership includes such costs as initial price of unit and attachments, delivery, and installation. In developing and analyzing cost information, other factors such as depreciation method, resale, overhaul and disassembly costs must also be considered. Operating and maintenance costs are the recurring costs which are required to keep the unit producing. They include such items as operator wages, fuel, lubrication, repair parts, license, insurance, and taxes [Ref. 34].

Too often the initial acquisition price dominates the cost analysis phase of the replacement decision. It is

considered, however, that the complete analysis must consider all costs. The basis of Life Cycle Costing discussed in Ref. 9 embraces such a concept and is endorsed by the writer. Certainly the magnitude in toto of all of the cost factors should emphasize their importance to the equipment manager.

2. Other Considerations

As noted previously, the line between decision elements listed as "criteria" and "other" is a fine one, perhaps even blurred. Nevertheless, factors on the periphery of the replacement decision are important to note and can have significant impact on both the means and the end of the process.

Equipment life figures set by policy or other means for certain classes of equipment are important base lines for many replacement decisions. As noted earlier it can be the "flag" to identify a unit for consideration. Thus, its importance lies in the fact that it can be a front-end input to the replacement problem as a particular unit enters the inventory. It is not to be mistaken as a driving factor in replacement for to do so overrides other factors which require analysis.

Use of the equipment has been discussed herein several times previously. The approach taken was concerned with its primary tasks immediately following procurement. Consideration of assignments following completion of the initial one are also of real importance. Secondary applications of older equipment to lighter tasks can often reap significant economies. The problem is, of course, the inability to foresee equipment

requirements several years downstream. For a given decision, however, old equipment in the current inventory, similar to that under replacement consideration, may be a viable alternative to a new equipment buy for some tasks.

Another factor is the procurement method utilized to replace the construction assets. Commercial firms utilize whatever method will maximize their benefits. Some organizations are required to procure equipment by certain methods as will be noted in Chapter V on the Navy approach. It is significant in that it precludes consideration of many factors which do indeed warrant consideration. It is a key to whether equipment procured in a given buy and in follow-on replacements will be of the same make. Maintaining the equipment "string" of the same make has important consequences in the repair parts support required, a factor which is further emphasized by equipment used in remote locations. The method also reflects the priority of considerations given to cost factors.

The type and reliability of cost data available upon which to base replacement decisions is important and is found to be a matter of concern to some theorists. In discussing maintenance costs, Mayer noted caustically that " . . . routine maintenance is a very straight forward operation, and theoretically, the amount of labor and material expended . . . can be measured. But any procedure developed to provide this information would entail so much administrative and clerical time that the value would be more than offset by the cost of procuring them."

[Ref. 12] Still, good data must be kept if analysis of existing equipment is to provide the basis for replacing with new equipment. The American Trucking Association's report said candidly, "Making management decisions based on erroneous information which one considers factual is more dangerous than knowingly making decisions based upon guesswork or intuition." [Ref. 3] Compilation of comprehensive, reliable data should be conceivably easier with computerization, where available.

These, then, are the decision elements which warrant deliberation when replacing equipment.

D. METHODS

It is the criteria input of construction equipment replacement decisions which is the concern of this thesis, not the determination of methods and formulae to which these criteria should be applied. It is considered, however, that at least a listing of some of the more widely acclaimed methods and formulae is in order. All methods cited point toward the replacement of capital equipment assets in general except for the Douglas Model which deals specifically with equipment used in the construction field.

1. Productivity Criteria Quotient (PCQ)
2. Payoff Period
3. Rate of Return
4. Present Worth
5. Annual Cost
6. Machine and Allied Products Institute (MAPI)
7. Simulation
8. Sensitivity Analysis
9. Risk Analysis
10. IBM Augmented Investors
11. Intuition or Hunch
12. Douglas Construction Equipment Model
13. Reeves Electronic Analogue Computer Analysis (REAL)

Methods 1 through 6 are discussed by Hackamack in Ref. 11 and Watson discusses methods 2 through 11 in his work [Ref. 34]. The Douglas Model was developed in Ref. 30; REAL was cited by Rand in Ref. 26.

IV. DIFFERENCES BETWEEN COMMERCIAL AND NAVY CONSTRUCTION

The final chapter deals with the comparison of the construction equipment replacement prescribed in theory and the commerical world with that used by the NCF and includes recommendations to enhance the effectiveness of the Navy system. There are, however, many differences between the theoretical/commerical construction arena and that of the Navy. Toward lending "real-world" credibility to this treatise, such differences are discussed briefly herein.

A. SPECIFIC JOB VERSUS GENERAL MISSION

In a very basic sense, the approach to construction equipment replacement is a function of the organization's whole reason for being, be it a commercial construction company or unit of the NCF. Commercial companies gear up for an equipment acquisition looking toward an upcoming project to build as opposed to a unit-by-unit replacement process per se. The buyer knows the specific use for which the equipment will be used; he can tailor his equipment requirement list to that future job. This is the short-term effect. In the long run he faces an uncertain, fluctuating pattern of construction opportunities very sensitive to the economy.

In contrast, the Navy equipment manager is concerned primarily with maintaining an equipment capability for contingency or emergency needs as opposed to projects to be built on specific upcoming Seabee battalion deployments. His approach is more general; he must consider mobility and flexibility along with the remoteness of operation inherent in such planning. On the other hand, the workload his equipment must support is relatively stable, predictable and insensitive to economic conditions.

B. FUNDING AND PROCUREMENT ENVIRONMENTS

Relative to the Navy process, the funding and procurement aspects of a replacement buy in industry is compact and unencumbered. One reason for this is that a construction company buys equipment in advance of a given project. At the outset of an equipment acquisition deliberation, the industry manager is aware of the amount of money available. If such an analysis is necessary to his approach to the matter, he has the wherewithal to rank alternative makes and models and execute the acquisition accordingly. Because all costs related to equipment are centralized, his analysis can integrate initial price, resale, operating and maintenance costs to support his ranking.

As will be discussed in more detail in Chapter V, his Navy counterpart is considerably more constrained. Federal funding is appropriated on an annual basis vice being project-specific which can cause considerable delay between the time the replacement determination is made and receipt of the equipment. In addition, he manages Navy equipment via two different types of

funds. One is specified for procurement only; the other is for operating the equipment. The problem precipitated by this is his not being able to combine funds in his analysis. Another matter is the requirement to buy through formal advertising. The Navy manager will have to accept the low bid regardless of how that vendor's equipment may have ranked with the alternatives. Thus, he is denied choosing the replacement model. The Navy equipment manager is also affected, significantly at times, by the prevailing political atmosphere. As an example, a requirement to fund at the same level every year for a given period seems to be the present vogue. While this minimizes some uncertainty (regarding the target figure for which to budget) it is not necessarily the most cost effective way to manage an equipment inventory. It further stresses what was heard by the writer several times in interviewing the Navy managers, "Money is the driver in the replacement process." These matters are discussed more comprehensively in the next chapter.

C. RENT/LEASE VERSUS BUY

The discussion of the option of renting or leasing as opposed to buying construction equipment will be succinct. In the commercial world of construction the rent/lease option is not only available but often chosen. It is not the intent of this work to probe the many reasons, supportable and otherwise, why the Navy always buys its construction equipment. Suffice it to say that it does.

A related matter is that of depreciation which the Navy is not concerned with since it does not pay taxes. However, a construction company which pays taxes in the 50% bracket is. The impact on its equipment management is that with all other things equal the pay-off period of a unit of equipment in industry is twice that of the same unit bought in the Navy.

D. VALUATION OF OUTPUT

In industry, the measure of effectiveness or achievement is often profits earned. It is a measurable thing. The cost of inputs, such as construction equipment costs, can be related to profit singularly or in an integrated manner and in so doing their contribution can be appraised objectively. The point is that a measurement can be made.

In comparison, the worth of the NCF mission is in terms of "the public good" which is subjective, a value judgment. Accordingly, the costs of components supporting that mission, which are measurable, cannot be related to the benefits derived. The process lacks a meaningful method to assess benefits gained from costs incurred.

E. COMPETITION

The contrast of the concept of competition between commercial and Navy construction is a vivid one. It is the name of the game in the construction industry and impacts on nearly every management decision made, including those relating to replacing capital assets. In comparison, the NCF operates primarily as a

single source with no organizations apparently competing for its mission. Accordingly, competiveness is not a factor in cost-effectiveness analysis of construction equipment replacement in the Navy.

F. MAGNITUDE OF OPERATION

This final difference is one which has an indirect effect on a given organization. To develop a comparison of one company's size to that of the NCF would serve no purpose. It is noted, however, that the magnitude and remoteness of the construction equipment supporting the Seabees is considerable. The equipment inventory numbers 7600 units deployed at any given time from Diego Garcia to Davisville, from Alaska to Antarctica. The point to be considered is that the magnitude and dispersal alone can prompt considerations in replacement that otherwise might not be necessary.

V. THE NAVY APPROACH

The two preceding chapters discussed the theory and commercial practice aspects of construction equipment replacement and noted the major differences between the nature of construction in industry and in the NCF. This chapter discusses organization, constraints and methods used by the Navy in its construction equipment management.

A. THE SYSTEM

1. The Civil Engineer Support Equipment Inventory (CESE)

The Naval Facilities Engineering Command (NAVFAC) manages Navy-owned equipment categorized by the following six Inventory Objective Elements:

a. Active Forces
b. Shore Activities
c. Reserve Shore
d. CNO Special Projects
e. Reserve Mobilization
f. Reserve Peacetime

The equipment utilized by these components known as Civil Engineer Support Equipment (CESE) includes motor vehicles, construction, weight-handling, railroad, firefighting and miscellaneous mobile equipment [Ref. 22]. The total value of the CESE inventory is $717 million and numbers over 67,000 units. This thesis is concerned with those forces making up the NCF (see Appendix B) shown as Active Forces. These forces utilize an equipment inventory valued at $132 million which is supported by another $87 million worth of equipment in ready stock.

2. Prepositioned War Reserve Stock (PWRS)

One aspect of the management of Navy CESE is the utilization of an inventory of mobilization equipment known as the Prepositioned War Reserve Stock (PWRS). This ready stock is located on both coasts to ensure a construction capability to support both Navy and Marine Corps operations on an emergency basis. It is a sizable, valuable asset which, as a secondary benefit, allows some flexibility in regard to management of Navy CESE.

One Naval officer contacted noted that basically all new CESE was rotated through PWRS. As noted in Ref. 23, "PWRS operates as a revolving account in which stock is rotated out to meet customer demands and replaced using (procurement) funds." PWRS equipment through-put is on a first-in, first-out basis. In addition to Navy units, other government agencies may acquire PWRS equipment assuming such an acquisition would not detrimentally affect the Navy readiness posture. When this occurs, the funds are transferred to CESO to cover the cost based on a replacement cost estimate vice what was actually paid for that specific equipment; these funds are used to acquire replacement equipment.

The advantages of PWRS equipment through-put are numerous. It reduces PWRS inventory average age and in so doing improves the overall state-of-the-art of the construction equipment readiness capability. In recent years, NAVFAC has not received procurement funds for new PWRS equipage precipitating a situation which would produce an obsolete mobilization stock in a relatively short period. Rotating new equipment through PWRS allows a continual inventory upgrading [Ref. 23]. Another advantage is the immediate delivery time to the fleet unit. This can be significant as one CESO officer noted that there is a two-year lead-time from authorization and funding to actual delivery in some types of equipment.

There are disadvantages. There is an inherent lag in the equipment state-of-the-art when it is received in the fleet several years after manufacture. Equipment managers tend to

discount this obsolescence being a major factor in NCF construction due to non-existence of competitive forces. Another disadvantage is that consideration of the PWRS system in the replacement decision tends to make the process which is already cumbersome even more so. Along these lines, the advantages seem to outweigh the disadvantages.

Netting it all out, it is noted that PWRS equipment through-put increases the flexibility of the Navy replacement decision maker.

3. The Civil Engineer Support Office (CESO)

NAVFAC discharges its equipment management responsibility through its Civil Engineer Support Office (CESO). Accordingly, CESO provides centralized procurement and inventory record maintenance [Ref. 23]. That it is the central manager is a significant point for it was noted that "CESE will be viewed as one Navy wide program with one inventory and one inventory objective vice three autonomous entities consisting of Shore, NCF and PWRS." [Ref. 18] Several years ago, criticism was leveled at the NCF equipment system citing problems which "prevail in the areas of overlapping jurisdiction of responsible agencies where accountability cannot be pinned down." [Ref. 16] The current management system utilized by CESO has solved this problem.

CESO has been called the "alter-ego of NAVFAC" for it must know what it takes to support the operating forces and what is the impact of degraded equipment. It must, therefore, be privy to future project requirements in order to balance

support overall [Ref. 27]. It is the decision maker regarding Navy CESE requirements, acquisition, maintenance, reassignment, replacement and disposal. It is tasked with control of this equipment from "cradle to grave" as one CESO representative described it.

Although it develops CESE requirements, CESO is not the contracting agency for equipment buys. The requirements are sent via Military Interdepartmental Purchase Request (MIPR) to the following agencies for procurement:

Trucks less than 10,000 lbs.	General Services Administration
Trucks greater than 10,000 lbs.	U. S. Army
Construction	Defense Construction Supply Center
General	Defense General Supply Center

Current policy is to specify commercial design equipment vice tactical design. This ostensibly reduces procurement costs and lead-time and, where such studies are made, should enhance comparability to construction equipment used in industry.

Each type of CESE falls under one of ten P-1 lines (listed in Appendix C) managed by a program manager who is the replacement decision maker. He is fully knowledgeable of all equipment in his P-1 line by USN number. NAVFAC requires each manager to "ensure the active inventory objective is met, using substitutes, interchangeability and retained overage assets in addition to new procurements . . . " [Ref. 21] Each manager, then, is responsible for development of replacement requirements which are the basis of the preliminary input to the annual budget.

At the origin of this process is the development of what is known as the Annual Allowance and Requirements Review (AARR). This is a computer print-out which summarizes an allowance holder's equipment on hand and considering equipment age identifies those CESE units which are eligible for replacement during a given budget year. The allowance review is conducted by the respective program manager and that activity's equipment officer. Each unit is studied along with any other unit which warrants replacement consideration as determined by the activity. The result of the "negotiation" between the CESO and activity representatives regarding which units are to be replaced and which are to be retained overage is a prime factor in developing the budget input.

Funds for equipment procurement are appropriated by P-1 line, and each program manager is authorized to manage those funds among Inventory Objective requirements within his line. A key to his management technique then is his ability to balance his line holdings among NCF, Shore and PWRS assets. A replacement problem facing some P-1 managers is that the average age of Shore Activities equipment has moved steadily upward because of higher priority NCF requirements several years ago resulting from Vietnam. Forty-nine percentage of the overall Shore CESE is overage in contrast to eight percentage for Active Forces [Ref. 18]. Assuming funding shortfalls, the efforts to cure the Shore problem will work to the detriment of the NCF average age if management of funds is not finely tuned. The ability to

utilize PWRS assets can definitely be advantageous. A primary tenet of CESO's current mission is to reduce the percentage of CESE retained overage to an "acceptable level" which was described by a CESO representative as 0% over the long range. The requisite capability and expertise is incumbent at CESO to achieve this and progress has been noted. Unfortunately, factors external to CESO impact heavily as will be noted in B below.

4. The Facilities Systems Office Computer (FACSO)

Equipment management is indeed a very complex task. Every capability that can be marshalled should be applied in order to increase effectiveness. Use of the computer can be a definite asset in terms of compiling voluminous data and subsequent analysis of that data. Although the industry representatives contacted did not allude to major emphasis of computer use in the area of equipment management, NAVFAC is currently making valid inroads in this field. An overview of the system to date is considered in order.

The necessity for a comprehensive data base was noted philosophically in Ref. 27, "The key to success in the PPBS world (Planning-Programming-Budgeting System of the Department of Defense) is the maintenance of a consistent data base. In the past we have at times been at different places trying to solve the same problem. This has been the source of most of our difficulties. CESO and NAVFAC must work together to bring that data base up to speed and then preserve it in a current state. That data base includes procedures, philosophy, positions on issues, etc., as well as raw numbers and facts."

Such a data base is under development at NAVFAC's computer facility, the Facilities Systems Office (FACSO). Unlike other systems commands under the Chief of Naval Material whose data bases are set up on an inter-command regional basis, NAVFAC maintains a central bank. In computer industry terminology, FACSO is the central design agency and the data processing service center for resources under NAVFAC, which includes CESE.

FACSO's equipment data bank, known as CASEMIS (Construction Automotive Support Equipment Management Information System), was developed with CESO to provide a single inventory, single replacement, data bank. CASEMIS will afford control data from registration to disposal. Three modules are planned:

a. Inventory and Registration
b. Planning, Programming and Budgeting
c. Operations and Maintenance

The first is currently being programmed and should be operational by mid-1975 and the remaining two phases are planned for future implementation [Ref. 23]. The second phase appears particularly relevant to the replacement problem.

Recognizing the future for such a system, its developers at both FACSO and CESO claim the design of CASEMIS is flexible enough to include future data needs whenever they become identified. CASEMIS was described as being "man-limited" as opposed to being "machine-limited." It is therefore presumed that storing and analyzing future data needs should pose no problems once they have been determined.

The present program will include the following information relevant to the replacement decision for each unit of CESE:

a. Age
b. Utilization
c. Labor hours and cost
d. Repair parts cost
e. Deployment record
f. Initial cost
g. Accumulated overhaul cost
h. Estimated replacement cost (based on current market prices, this is updated at each AARR).

Expanded data needs and the commensurate computer capability is considered a given. Appropriate planning seems currently underway.

B. CONSTRAINTS ON THE SYSTEM

An autonomous organization is, by definition, not subject to external regulation and guidance. Suffice it to say that the construction equipment replacement decision in the Navy is not made by an autonomous agent. Regulations or guidance handed down are not normally done so with the intent to constrain subordinates in a manner detrimental to the mission. At times, however, certain tenets of policy seemingly run counter to the benefit of a given decision or process.

1. Procurement Method

As a matter of general policy, the Department of Defense (DOD) embraces the concepts known as "economic analysis" and "program evaluation." The latter, which seems more relevant to the equipment replacement decision, was defined in Ref. 8 as a type of economic analysis of " . . . on-going actions to determine how best to improve an approved program/project based on

actual performance . . . (It) focuses on approved programs and projects to ensure that established goals and objectives are being attained in the most cost-effective manner." It directed a cost analysis of all alternatives available including maintaining the status quo or doing nothing. It went on to note that cost analysis should include all recurring operating costs and comparisons of schedule and performance.

Related to this is the concept known as Life Cycle Costing (LCC) described in Ref. 9 as an acquisition technique " . . . which considers operating, maintenance and other costs of ownership as well as acquisition price . . . The objective is to insure that the equipment procured will result in the lowest overall ownership cost to the Government during the life of the equipment . . . LCC analysis should include all anticipated expenditures directly or indirectly associated with an alternative."

The foregoing serves well to describe the philosophy of the federal government regarding analysis supporting capital investment. The problem is, however, that there is an overriding regulation which for all intents and purposes requires that construction equipment be procured through formal advertising. Thus it is that competitive bidding produces a lowest bidder who will receive the award for new equipment. The Armed Services Procurement Regulations (ASPR) allow procurement through negotiation vice competitive bid under 17 excepting circumstances; unfortunately, CESE normally does not qualify for any of these.

The reasons for government procurement by competitive bid will not be discussed here. That formal advertising seems counter to DOD's bent toward thorough economic analysis warrants further coverage.

First, the U. S. Code (10 USC 2305 (c)) notes that competitive bids will be evaluated to determine the one "most advantageous to the government, price and other factors considered" (emphasis added). Admittedly, the letter of the law may intend for due consideration of all applicable factors. In reality, the spirit of the law is construed to empahsize the price. The lowest acquisition price in no way assures the "most advantageous" alternative. In fact, sound management requires the cost analysis over the long term not just the price paid at buy time. As noted in Ref. 9, "one offeror's equipment may cost less to buy but more to maintain and operate over the length of time the item is programmed to remain in the inventory." Consideration of durability, maintainability and productivity is too easily precluded by formal advertising and its inherent price emphasis.

Secondly, this procurement method is apt to affect a construction equipment manager's approach to his analysis of alternative buys. Just possibly he could perceive that such analysis is futile because it will be pre-empted by the low-price bidder. Thus, critical long-term factors become subordinate in the decision-maker's view.

Finally procurement by formal advertising does not permit the decision maker the capability to project a downstream profile of his inventory. The successful bidder during one procurement may not receive the award on the follow-on contract several years hence for the same type of equipment. This results in a mixed string of equipment which encompasses its own problems. A one-make inventory is far and away the most effective to manage. As noted in Chapter III, such factors as equipment support magnify themselves considerably when the jobsite is remote, as is so often the case for NCF deployments.

At present, there is virtually no means to control award selection. This minimizes the desired effect that could be achieved with economic analysis.

2. <u>Budget Limitations</u>

The idea of budget limitations is not new, nor is it unique to Navy construction equipment replacement. It is a fact of life and is at the heart of why scarce resources are just that. Unlimited coffers would allow all to have everything they wanted and eliminate the majority of reasons to analyze alternatives. There is, however, a problem confronting Navy CESE managers in this regard. It is that it takes many months after determination of requirements for notification of what exact amount of funding will be appropriated, if any. The impact can be at least twofold. One, during such a delay, changes in requirements can be measurable. Secondly, each ensuing month means that much more inflation. With a given

amount of funds, a price increase dictates a quantity decrease. These factors serve to enhance the need for economic analysis. Reference 26 notes, " . . . it may be argued that despite the revealed economy in making replacements, (possibly) none will be made because of unavailability of capital funds at a particular time. This does not mean that we should ignore the problem; at worst, the case for replacement expenditures can be strengthened and at best, when funds are available, they can be spent in the most economical directions." In industry, at least one construction company cited the equipment need as the prime "driver" in the replacement process. In contrast, as was noted by one Navy representative, funding is the driver in the NCF arena.

In an effort to minimize the detrimental effect of uncertainty regarding how much money will be appropriated yearly for CESE replacement procurement, a concept known as Level Funding Requirement (LRF) was inaugurated in late 1974. The idea is to project several years into the future the uniform level of funding required to maintain an inventory of equipment with 0% overage. It is predicated on the belief that identifying such a funding need over the long term will increase the probability of Congressional funding at the desired dollar level. It entails detailed planning and programming but that is not considered unreasonable. It further requires determination of an overall turnover rate for a complete inventory, ten years in the case of Navy CESE. Reference 18 briefly describes LFR as follows:

> An overall turnover rate of ten years . . . means the average piece of CESE should not be in the system more than ten years. Previous CESE budgets have been justified on the amount of overage equipment that requires replacement . . . A level funding concept is based on the inventory objective and equipment turnover rate rather than stressing the dollars required to replace overage equipment. The turnover rate for CESE is ten years and if we are able to replace one-tenth of the inventory every year for ten years we will achieve a situation where approximately 10% of the CESE becomes overage each year, thus eliminating the problems of (1) high maintenance costs associated with an inventory 40% (Navywide) retained overage assets and (2) volatile annual dollar requirements needed to replace overage equipment. With a $717 million inventory and 18% inflation the LFR for FY-76 equals
>
> $$\left(\frac{\$717\text{ M}}{10} \right) \text{ X } (1.18) = \$84.6\text{ M}$$

LFR ostensibly determines beforehand the amount of money to be appropriated. By dealing with this uncertainty in this manner it seems to minimize a major facet of limited funding.

3. Funds Classification

The federal funding system classifies monies appropriated by functional use. As might be expected, specific use of an appropriation is rigidly regulated; application of the funds for some use other than specified by Congress is prohibited. There are two appropriations relevant to Navy CESE management. Because funding top management's interest in their particular appropriation seems to override their concern for overall cost-effectiveness, a problem exists which is, perhaps, unnecessary.

The two appropriations involved are entitled Other Procurement, Navy (OPN) and Operations & Maintenance, Navy (O&MN).

The former is the acquisition money, the procurement cost to replace equipment retired from inventory. The latter pays for the recurring costs, the operating and maintenance funds to keep a unit producing [Ref. 24]. The problem perceived is that the OPN and O&MN managers are decentralized and separate analysis of the two funds is conducted. This results naturally in an emphasis by OPN personnel to minimize procurement prices and O&MN managers stressing minimal operating and maintenance costs. Achieving both, of course, would approach an optimal solution. In actuality, however, the least expensive to buy can be the most costly to operate. Because OPN and O&MN funds cannot be comingled, the vested interests remain dichotomized. The net effect is that the CESE decision maker who is tasked with managing both types of funds at his low-level probably recognizes the problem but is unable to solve it; his analysis cannot incorporate the combined (OPN, O&MN) long term effects in guiding his replacement decision. If, as stressed by ASPR, total overall cost is the true benchmark, combined analysis of all funding involved must be effectively achieved.

One other peripheral point was noted by a CESO representative. Funds received from disposal of retired equipment do not revert back to the Navy and therefore are not available for equipment replacement due to funding regulations. Accordingly, salvage value is not considered in replacement determinations.

C. CRITERIA

As alluded to in previous chapters, capital equipment replacement whether accomplished in industry or the Navy has many common aspects. The goal is the same; the players and sometimes the rules are different. Quite similar to those definitions quoted in Chapter III, DOD's concept of economic life of a capital investment is " . . . the period of time over which the benefits to be gained from a project may reasonably be expected to accrue . . . it is limited by its physical life and further limited by its technological life." [Ref. 10] However, differences were noted in the approach to the criteria used in making equipment replacement determinations.

1. The Emphasis on Age

When the writer inquired specifically as to what criteria were used in CESE replacement decisions, the CESO representatives in a very straightforward manner cited only two: age and judgment, with age the basic one. The same reasons for using age discussed in the Theoretical/Commercial chapter apply equally well to Navy use: its explicit and finite nature, its ease of measurement. Likewise as discussed, the traits inherent in the specific definition of "age" in a given process also warrant attention in the Navy arena.

In mid-1974 CESO developed life expectancies for each equipment type which it calls "Seabee Life" and upon which future replacement requirements are based:

Seabee Life = Years in PWRS + DOD Field Life *

*Based on anticipated life determined by DOD on a department-wide basis.

(If the calculation noted above was greater than the years parts support could be effectively rendered by the equipment manufacturer, the parts support period would become the "Seabee Life" for that unit.)

The formula accomplished two important functions. One, it explicitly noted the unique characteristic pertaining to the amount of storage time in the mobilization inventory. Secondly, it duly noted the DOD equipment life criteria.

There can be little doubt that age is the basis of the Navy equipment replacement process. It is the base-line, the start-point of replacement deliberations. Other criteria are indeed secondary.

2. Other Criteria

These other secondary criteria which are considered in the replacement decision are discussed below. The reader should not infer that all factors cited herein are a part of every decision; certainly that is not the case.

a. Usage

Depending on the type of machine, usage is measured in either hours or miles. It is often the sister criteria to age in automotive replacement tables, e.g., "six years or 72,000 miles." In discussions with CESO representatives, the writer noted that usage is a significant factor only in extreme cases where use of a given equipment was very low or very high relative

to its age. Obviously, high use was a factor in favor of replacement and conversely.

b. Extensive Repair

Unexpected replacement deliberations are precipitated upon the occurrence of traumatic accidents with equipment as noted in Chapter III. The decision to incur extensive repair costs must be made deliberately and as a matter of policy operating units are required to defer to the judgment of CESO when repair costs reach certain magnitudes relative to the equipment's acquisition cost. A factor for age is also cranked into the deliberation.

In further elaboration to the two aforementioned criteria, a recent U. S. Air Force action is worth noting. Prior to Fiscal Year 1968 (FY68) the USAF recommended replacement of motor vehicles when any one of the following three criteria were exceeded: age, miles or one time repair cost. In response to a Congressional funding review, replacement was changed to a dual criterion of either age and miles or age and one-time repair cost for FY68 through FY71. The findings determined that " . . . changing to the dual criteria had contributed to the present (deterioration) problems in the fleet status. Operating and maintenance costs for administrative-use vehicles, for example, increased over $110 per vehicle." [Ref. 1] This seemed to indicate that subordination of some criteria to age is not necessarily effective.

c. Block Buying

Even though each and every CESE replacement is handled on a unit-by-unit basis, the inventory is also managed on an "equipment family" basis. Accordingly, some units of equipment that otherwise might qualify for replacement may be deferred a year or so to make up a quantity buy. This may result in a volume price break but it may also produce block aging.

d. Need and Flexibility

The CESE manager's approach to the requirement for the equipment is based not so much on specific NCF deployment projects as on the capability to be maintained in readiness to support contingency plans. The net result is that requirement considerations at replacement time are slanted in the direction of general, i.e., flexibility, vice specific use.

e. Maintainability

This factor is not specifically considered in the replacement process. In interviews with CESO personnel concerned with the specific subject of equipment maintenance, recommendations were noted to include such a consideration. In this regard there is a Maintenance Management Information System (MAINTMIS) under development and is expected to be an appendage to CASEMIS indicating that sometime in the future maintenance factors can be analyzed and included in all equipment decisions.

f. Obsolescence

The concept of obsolescence was broached by several Navy equipment personnel in a manner which indicated it is a criteria which is not used. One CESO representative noted, "Obsolescence is no factor due to Seabees wearing equipment out before it can become obsolete." Sutley noted in Ref. 12, "Obsolescence . . . is impossible to forecast much in advance of its occurrence . . . State-of-the-Art advancements in construction equipment have historically been slow." This type of rationale plus the lack of forces competing for the NCF mission seems to negate the need for Navy CESE managers to consider obsolescence.

g. Salvage Value

For reasons cited in Section B above, salvage or resale value of equipment is not a replacement consideration as noted by CESO representatives. Unless funding regulations are changed drastically, such a consideration is not foreseen as likely.

It is noted then that while other criteria besides age may apply to the Navy equipment replacement decision, their use in actuality is secondary.

VI. CONCLUSION

Notwithstanding the amount of attention which was devoted to the theoretical and commercial considerations of replacing construction equipment, the primary interest remains an appraisal of the Navy approach. Accordingly, observations and recommendations set forth herein are so oriented.

A. OBSERVATIONS

Several observations on the subject of Navy construction equipment management were noted which are significant in the writer's mind as this finalization is set to paper to warrant mention. The first is the thesis subject itself: replacement of Navy construction equipment <u>is</u> based on one primary criterion--age. Other criteria were noted but their inclusion in the replacement analysis appears the exception rather than the rule. Thus, the existence of a single replacement criterion is considered as real in the final stages as it was apparent in the initial one. It is opined that while the present system is effective, it could be improved.

A positive observation relates to the centralized organization developed to manage the CESE inventory. The organization, personnel and facilities appear amply capable of achieving their mission. The management for such an extensive and scattered inventory is effectively centralized yet apparently responsive to its many customers. CESO personnel are considered by the

writer to be experienced, objective, and professional. The facilities at their disposal, primarily the FACSO computer bank, seem second to none. Nothing required for optimal equipment management seems to be lacking at CESO.

Another phenomenon noted was the recognition of the need to solve equipment problems on a long-term basis. Admittedly, impetus in this direction has originated above CESO and even NAVFAC in the form of such things as PPBS and LFR. Nevertheless, the approach to such policies at CESO was observed to be positive, recognizing the beneficial long-range aspects.

One other positive action observed was the process of rotating new equipment through PWRS. The writer is unaware of the reasoning which initiated this technique but considers it an exercise of alert management. The atmosphere of constrained budgeting which precluded appropriation of funds to upgrade mobilization stocks while at the time not allowing replacement of active force support equipment as needed presented a two-edged sword. The concept presently followed which transfers newly acquired unused equipment from PWRS inventory to operating forces as brand new, like units that enter stock as replacements solves both problems. That represents the type of imaginative management required under the current state of limited resources.

B. RECOMMENDATIONS

Based on the research and information gathered in preparation of this thesis, four recommendations are presented below. In

keeping with the intent to present a paper that is not just theoretical but also has some "real-world" relevance, the writer notes that only the first three recommendations are attainable. The last one would require something akin to major surgery of the federal system; thus, it is considered possible but not in the least bit probable.

1. <u>Six Valid Criteria Are Relevant</u>

Age, Usage, One-Time Repair Costs, Maintainability, Productivity and Resale Value are recommended herewith as criteria which should be explicitly considered in a Navy construction equipment replacement decision.

The term "explicitly consider" does not infer that all six criteria will affect replacement in each final analysis. It does mean that each criterion should be considered at the outset of deliberations. To a varying degree the six are measurable, analyzable and relevant.

Prescribing five other criteria as potential coequals to that of age is not intended to subordinate the continual close look at that factor, such as the analysis which was the basis of the development of "Seabee Life." To the contrary, it is analysis of this type which leads to a better understanding of the entire process.

It is recognized that "instant relevance" cannot be achieved in regards to a development of a multiple-criterion. Accordingly, it is considered that an appropriate approach would be to gather data pertaining to a major equipment family and

through a process such as sensitivity analysis develop criteria relationships. It is further recognized that development and evaluation of even pilot programs would take years. In addition, varying factors such as equipment makes, models and uses need to be normalized. With the computer processing capability and storage capacity available at FACSO, such analysis is not beyond reason. It is a foregone conclusion that the funding constraints on NCF equipment, particularly in peacetime, will continue to tighten; better management techniques will be necessary to meet the challenge.

2. <u>An Effective Management Information System is Necessary</u>

Because of the magnitude of the capital investment of the NCF construction equipment inventory and the complexity of the factors inherent in its sound management, it is recommended that the development of a comprehensive equipment information system be aggressively pursued.

The CASEMIS data bank represents the type of approach necessary. Presently in an embryonic stage, it shows great potential. That potential will lie dormant, however, without dynamic personnel to push its further development. These personnel are of two types: computer-oriented and CESE-oriented. It is considered that the impetus to full development must by necessity be provided by the CESE people. This will involve removal of some personnel inertia in convincing equipment managers that CASEMIS can be an extremely valuable tool to them. As users of the finished system, their contribution to its development

can and should be significant. It is human nature for an individual to make more effective use of a system he helped develop. This applies to both design of the data-storage system and of analysis programs to assist them in their equipment decisions.

Data, of course, should not be stored for storage sake. It has no value if it is not used and analyzed by management. A Secretary of the Navy Instruction noted "replacement decisions are concerned with only future value. Neither the equipment's original cost nor the vehicle's past maintenance cost is a controlling factor" (emphasis added) [Ref. 29]. This reflects, of course, the sunk cost concept. This writer, however, takes exception to this to a degree. It is considered that the concept of analysis which develops relationships would be more beneficial if it provides also a look backward. Something can be learned from past performance and effective analysis should provide a means to compare planned output to actual.

3. Procurement Method Should Be Compatible With Emphasis On Economic Analysis

It is recommended that as economic analysis continues to be emphasized by DOD, a procurement method more compatible than the Formal Advertising method currently used be adopted for construction equipment acquisition.

Contracts awarded through Formal Advertising usually go to the lowest bidder; the basis of replacement equipment selection is the lowest acquisition price. This is in accordance with regulations. Running somewhat counter to this is DOD

policy stating that capital investments should be subjected to economic analysis to determine the total life costs to the government. The latter seems to home in on the cost-effectiveness issue much more closely than the former. Conducting the extensive analysis required to develop a valid ranking of alternatives seems a futile exercise. Low price will override all else.

It appears to the writer that a more effective procurement method would be analysis of the alternatives based on a Life Cycle Costing (LCC) or similar, issue Requests for Proposals (RFP) and negotiate. ASPR cites 17 exceptions to Formal Advertising that may be procured through Negotiation. Exception (13) allows negotiation for " . . . equipment which (the Secretary of the Navy) determines to be technical equipment whose standardization and the interchangeability of whose parts are necessary in the public interest and whose procurement by negotiation is necessary to assure that standardization and interchangeability." [Ref. 4] It further requires that the equipment be for tactical use at advanced or detached bases (among others), that the exception determination be reviewed at least biannually, that the exception be applied only to subsequent or follow-on purchases (vice initial buys) and that a recurring requirement for the equipment exists. It is considered that Seabee construction equipment meets these criteria. Justification for Secretarial approval to procure particularly the more complex NCF equipment by Negotiation seems indeed feasible.

4. <u>Procurement (OPN) and Operating (O&MN) Costs Should Be Combined To Analyze Them Corporately</u>

It is recommended that a method be developed to combine OPN and O&MN cost analysis to achieve an overall low cost.

This recommendation is related to third-order-head Three above in that both seek to improve the viability of analysis in the procurement process. It was apparent to the writer that the parochiality of the managers of the two types of funds, while earnestly intending to achieve what is best in their area of responsibility, could be working to the detriment of the achievement of true overall cost-effectiveness. To circumvent this, Navy top management would have to endorse combined costs examination at the lower procurement management levels, something not now achievable.

The problem discussed is a dynamic one, subject to varying factors from both the construction aspects and other factors from external sources, like Congress and the economy. It is because of its dynamic dimension that managing Navy CESE will never be subject to a final, optimal method. Like all management, astute judgment, art as well as science, and focused thinking must play their part to achieve sound decisions here. It is concluded that while Navy construction equipment is presently being managed effectively, it could be improved.

APPENDIX A

KEY NAVY PERSONNEL CONTACTED

LCDR Paul W. Bonham, CEC, USN, Material Management Division, NAVFAC.

LCDR James Callahan, CEC, USN, Head, Equipment Management Department, CESO.

Mr. Donald Davidson, Management Support Office, FACSO.

Mr. Raymond E. Ewin, Director, Plans and Programs Division, CESO.

Mr. Gary Lind, P-1 Program Manager, CESO.

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CWO3 M. G. Thatcher, CEC, USN, Director Maintenance Division, CESO.

LCDR J. D. Woll, CEC, USN, Director, FACSO.

APPENDIX B

ACTIVE FORCE REQUIREMENTS

2	Amphibious Construction Battalions
8	Naval Mobile Construction Battalions
15	Construction Battalion Units
2	Naval Schools Construction
2	Beachmaster Units
1	Beach Group
2	Assault Craft Units
2	Naval Inshore Warfare Commands
1	Cargo Handling and Port Group
12	Mobile Technical Units
1	Naval and Support Team
2	Harbor Clearance Units
2	Training Units
5	Seabee Teams
2	Underwater Construction Teams
1	Construction Battalion Maintenance Unit
1	Naval Construction Regiment Deployed

APPENDIX C

CESO P-1 EQUIPMENT LINES

P-1 No.	Line	Contracting Agency
1	Passenger Carrying	GSA
2	Trucks	GSA, TACOM
3	Trailers	TACOM
4	Crushing, Mixing, Batching and Paving	DCSC
5	Drilling and Blasting	DCSC
6	Earthmoving	DCSC
7	Light and Power Generating	DGSC
8	Miscellaneous Construction	DGSC, NRPO LB
9	Firefighting	CBC Davisville
10	Weight Handling	NRPO LB

CBC Davisville	U. S. Naval Construction Battalion Center, Davisville, Rhode Island.
DCSC	Defense Construction Supply Center, Columbus, Ohio.
DGSC	Defense General Supply Center, Richmond, Virginia.
GSA	General Services Administration, Washington, D. C.
NRPO LB	Navy Regional Procurement Office, Long Beach, California
TACOM	U. S. Army Tank and Automotive Command, Warren, Michigan

Ref. 18

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